(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification⁷: H04B 7/00

(21) International Application Number: PCT/IB01/00254

(22) International Filing Date: 26 February 2001 (26.02.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0004557.5   25 February 2000 (25.02.2000)   GB

(71) Applicant (for all designated States except US): MO-TOROLA ISRAEL LIMITED [IL/IL]; Kremenetski Street 16, 67899 Tel Aviv (IL).

(72) Inventors; and
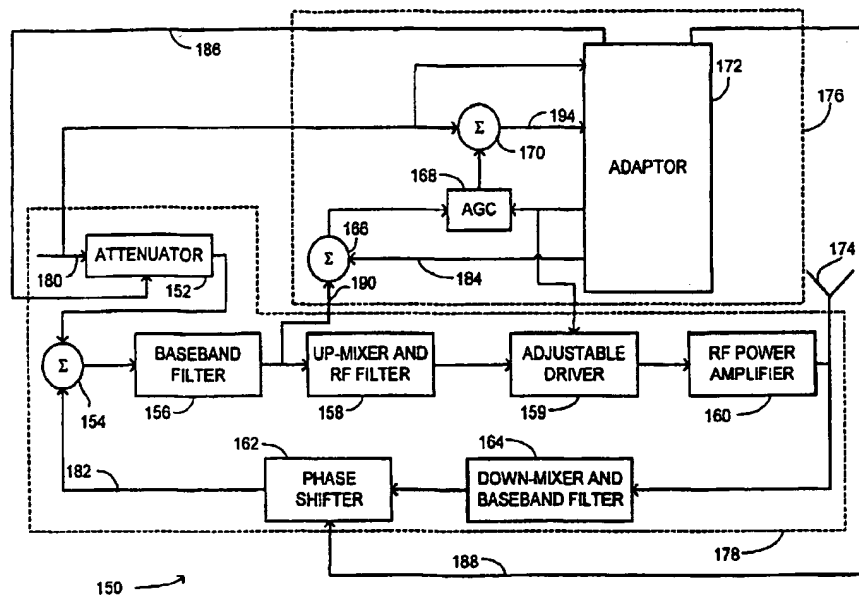(75) Inventors/Applicants (for US only): BEN-AYUN, Moshe [IL/IL]; 27 Hayasmin_Street, P.O.Box 3026, 73142_Shoham (IL). ROZENTAL, Mark [IL/IL]; Apartment 8, Herzel Street 29, 76560 Rehovot (IL).

(81) Designated States (national): AL, AM, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, EE, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, RO, RU, SD, SG, SI, SK, SL, TJ, TM, TT, UA, UG, US, UZ, VN, YU, ZW.

(84) Designated States (regional): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS FOR LINEAR TRANSMITTER WITH IMPROVED LOOP GAIN STABILIZATION

(57) Abstract: A device for a linear transmitter (150) with improved loop gain stabilization. The linear transmitter (150) includes a main amplifier loop (178) and an auxiliary loop (176). The device includes an adjustable driver (159), connected within the main amplifier feedback loop (178) and further connected to the auxiliary loop (176). The adjustable driver (159) receives an input signal from main amplifier feedback loop (178), amplifies it in accordance with a gain control signal received from the auxiliary loop (176) and provides the amplified signal to main amplifier feedback loop (178).

Apparatus For Linear Transmitter With Improved Loop Gain Stabilization

Field Of The Invention

The present invention relates to radio frequency transmitters in general, and to linear radio frequency transmitters having a varying antenna load, in particular.

Background Of The Invention

Radio communication devices use antennas to provide efficient transmission of radio frequency communication signals. The transmission portion of a communication device includes a power amplifier for amplifying the radio frequency signals before they are coupled to the antenna for transmission. The power amplifier design often relies on constant load impedance which is directed at maximizing gain, efficiency, power output level, and the like. The behavior of a transmitter may be affected by its operating environment. For example, a transmitter operating near an electromagnetically reflective structure may be susceptible to energy reflected back through the antenna into the transmitter. Reflective energy may be detrimental to transmitter performance, particularly to the performance of the power amplifier. An isolator or circulator is often inserted between the antenna and the power amplifier to protect against changes in load impedance as a result of reflected energy.

The isolator protects the power amplifier by absorbing the reflected energy and preventing it from reaching the amplifier. The isolator directs the reflected energy to an absorptive load termination. An isolator typically adds significant cost, size and weight to the design of a radio communication device.

US Patent 5,564,087 to Cygan et al., entitled "Method and apparatus for a linear transmitter" discloses another solution to the problem of reflected energy. The solution incorporates a directional coupler to detect the reflected energy and provides a means of adjusting the gain of the power amplifier accordingly. Generally, the gain to the power amplifier is reduced when high levels of reflected energy are present. In this approach, the circuitry for detection of the reflected

energy must operate at the transmission frequency. This adds significant cost and complexity to the radio design.

US Patent 5,675,286 to Baker et al., entitled "Method and apparatus for an improved linear transmission", is directed to a method and apparatus for isolator elimination, operative at the baseband frequencies, which is described in detail, herein below. Reference is made to Figure 1, which is a schematic illustration of a linear transmitter block of a radio communication device, generally referenced 50, which is known in the art. Transmitter block 50 includes an attenuator 52, three summators 54, 66 and 70, a baseband loop filter unit 56, an up-mixer and radio-frequency (RF) filter unit 58, an RF power amplifier 60, a down-mixer and baseband filter unit 64, a phase shifter unit 62, an AGC 68, an adaptor unit 72 and an antenna 74. Summator 54 is connected to attenuator 52, to baseband filter unit 56 and to phase shifter unit 62. Summator 66 is connected to baseband filter unit 56, to up-mixer and RF filter unit 58, to adaptor unit 72 and to AGC 68. Summator 70 is connected to AGC 68, to attenuator 52 and to adaptor unit 72. Adaptor 72 is further connected to AGC 68, to attenuator 52 and to phase shifter unit 62. Up-mixer and RF filter unit 58 is connected to baseband loop filter unit 56 and to power amplifier 60. Down-mixer and baseband filter unit 64 is further connected to power amplifier 60 and to phase shifter unit 62. Antenna 74 is connected to power amplifier 60 and to down-mixer and baseband filter unit 64.

A signal 80 is provided as input to amplifier feedback loop 78 and to isolator elimination circuit 76. Amplifier feedback loop 78 and isolator elimination circuit 76 represent the main amplification loop and the auxiliary loop, respectively. Amplifier feedback loop 78 is a closed loop amplifier structure. Typically, this structure can be considered a Cartesian feedback loop amplifier. The input signal 80 is generally a complex digital baseband signal, having quadrature components, i.e. in-phase (I) component and quadrature (Q) component. Signal 80 is provided to attenuator 52. Attenuator 52 provides an attenuated signal to summator 54. Summator 54 combines this signal with a feedback loop output signal 82 and provides a resulting error signal to baseband filter unit 56. Baseband filter unit 56 provides the filtered error signal to up-mixer and RF filter unit 58. Up-mixer and RF

filter unit 58 up-converts the signal to RF and provides it to power amplifier 60. Power amplifier 60 amplifies the signal and provides the amplified signal to antenna 74 for transmission. Antenna 74 forms a load for power amplifier 60. It is noted that this load is susceptible to impedance variations due to its operating environment. Power amplifier 60 provides a portion of the output signal to summator 54, via down-mixer and baseband unit 64 and phase shifter unit 62, thereby generating feedback loop output signal 82. Feedback loop output signal 82 constitutes a feedback signal for controlling the gain of power amplifier 60 and maintaining transmitter block 50 in the linear mode of operation.

Baseband filter unit 56 also provides a filtered error signal 90 to summator 66. Summator 66 combines error signal 90 with signal 84 from adaptor 72 and provides the result to AGC 68. AGC 68 constitutes a linear gain control circuit of isolator elimination circuit 76. Adaptor 72 controls the gain of AGC 68 by altering the output signal of AGC 68. AGC 68 provides the output signal to summator 70, where it is combined with input signal 80. Summator 70 provides the resulting error signal 94 to adaptor 72, which produces two output control signals 86 and 88. Control signal 86 adjusts the gain of attenuator 52, and control signal 88 adjusts phase shifter 62. Adaptor 72 produces control signals 84, 86 and 88 based on input signal 80 and error signal 94.

In order to optimise the function of the design above, it is necessary to design a transmitter with sufficient gain and/or power reserve. Such a design will result in increased complexity, cost, power consumption and more. There is a trade-off between the desired design simplicity and cost-effectiveness on one hand, and necessary dynamic range of the system gain and/or output power, on the other hand. It is desirable to provide a linear transmitter, which is cost-effective and simple, yet assuring linear performance and high signal-to-noise ratio.

United States patent US-A-5542096 to Cygan et al. is entitled 'Method for a Transmitter to Compensate For Varying Loading Without An Isolator'. In US-A-5542096, figure 1 shows a linear transmitter. In the transmitter, a variable gain stage is located between a summing junction 102, and a mixer 120.

Summary Of The Invention

It is an object of the present invention to provide a novel method and device for a linear transmitter with improved loop gain stabilization, which alleviates the disadvantages of the prior art.

In accordance with the present invention, there is thus provided a device for minimizing performance degradation of a linear transmitter block of a radio communication system. The linear transmitter block includes a main amplifier feedback loop and an auxiliary loop. The device includes an adjustable driver, connected within the main amplifier feedback loop and further connected to the auxiliary loop.

The adjustable driver receives an input signal to be amplified from the main amplifier feedback loop and a gain control signal from the auxiliary loop. The adjustable driver amplifies received input signal in accordance with the value of the gain control signal and provides the amplified signal to the main amplifier feedback loop.

In accordance with a further aspect of the present invention, the main amplifier feedback loop can include an attenuator, a baseband filter, an up-mixer and RF filter unit, an RF power amplifier, a down mixer and baseband filter unit, a phase shifter and a summator. The summator is connected to the attenuator, to the up-mixer and RF filter unit and to the phase shifter unit. The adjustable driver is connected to up-mixer and RF filter unit and to the RF power amplifier. The down-mixer and baseband filter unit is connected to the RF power amplifier and to the phase shifter unit.

In accordance with yet a further aspect of the present invention, the auxiliary loop includes an adaptor, an AGC and two summators. The first summator is connected to the baseband filter unit, to the adaptor and to the AGC. The second summator is connected to the attenuator, to the AGC and to the adaptor. The adaptor is further connected to the attenuator, to the phase shifter unit, to the AGC and to the adjustable driver.

The input signal to be amplified constitutes a first baseband error signal, filtered by the baseband filter and up-converted by the up-mixer and RF filter unit.

The first baseband error signal is provided by the summator and constitutes a sum of a baseband signal and an output signal of the main amplifier feedback loop. The baseband signal is an input baseband signal attenuated by the attenuator. The attenuation gain of the attenuator is controlled by a first output signal from the adaptor. The output signal of the main amplifier feedback loop is a result of down converting by the down-mixer and baseband filter unit, and phase shifting by the phase shifter of a portion of an output RF signal provided by the RF power amplifier. The phase shifter is controlled by a second output signal from the adaptor.

In accordance with a further aspect of the present invention, the adaptor provides to the adjustable driver the gain control signal. This gain control signal is a result of a comparison between the input baseband signal and a second baseband error signal, provided by the second summator of the auxiliary loop. The second baseband signal is a sum of the input baseband signal and an output signal from the AGC. The output signal from the AGC is a result of a comparison between the gain control signal and a third baseband error signal provided by the first summator of the auxiliary loop. The third baseband error signal is a sum of a third output signal from the adaptor and the first baseband error signal, provided by the baseband filter.

Brief Description Of The Drawings

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

Figure 1 is a schematic illustration of a linear transmitter block of a radio communication device, which is known in the art; and

Figure 2 is a schematic illustration of a linear transmitter block of a radio communication device, constructed and operative in accordance with a preferred embodiment of the present invention.

Detailed Description Of Preferred Embodiments

The present invention overcomes the disadvantages of the prior art by providing an adjustable driver for improving loop gain stabilization.

Reference is now made to Figure 2, which is a schematic illustration of a linear transmitter block of a radio communication device, generally referenced 150, constructed and operative in accordance with a preferred embodiment of the present invention. Transmitter block 150 includes an attenuator 152, three summators 154, 166 and 170, a baseband loop filter unit 156, an up-mixer and radio-frequency (RF) filter unit 158, an adjustable driver unit 159, a RF power amplifier 160, a down-mixer and baseband filter unit 164, a phase shifter unit 162, an AGC 168, an adaptor unit 172 and an antenna 174. Summator 154 is connected to attenuator 152, to baseband filter unit 156 and to phase shifter unit 162. Summator 166 is connected to baseband filter unit 156, to up-mixer and RF filter unit 158, to adaptor unit 172 and to AGC 168. Summator 170 is connected to AGC 168, to attenuator 152 and to adaptor unit 172. Adaptor 172 is further connected to AGC 168, to adjustable driver 159, to attenuator 152 and to phase shifter unit 162. Up-mixer and RF filter unit 158 is connected to baseband loop filter unit 156 and to adjustable driver 159. Power amplifier 160 is connected to adjustable driver 159 and to antenna 174. Down-mixer and baseband filter unit 164 is connected to power amplifier 160 and to phase shifter unit 162. Antenna 174 is connected to power amplifier 160 and to down-mixer and baseband filter unit 164.

A signal 180 is the input signal to an amplifier feedback loop 178 and an isolator elimination circuit 176. Amplifier feedback loop 178 and isolator elimination circuit 176 represent the main amplification loop and the auxiliary loop, respectively. Amplifier feedback loop 178 is a closed loop amplifier structure. Typically, this structure can be considered a Cartesian feedback loop amplifier. The input signal 180 is generally a complex digital baseband signal having quadrature components, i.e. in-phase (I) component and quadrature (Q) component. Signal 180 is provided to attenuator 152. Attenuator 152 provides an attenuated signal to summator 154. Summator 154 combines this signal with a feedback loop output

signal 182 and provides a resulting error signal to baseband filter unit 156. Baseband filter unit 156 provides the filtered error signal to up-mixer and RF filter unit 158. Up-mixer and RF filter unit 158 up-converts the signal to RF and provides it to adjustable driver 159. Adaptor 172 controls the gain of adjustable driver 159. Adjustable driver 159 provides the output signal to power amplifier 160. Power amplifier 160 amplifies the signal and provides the amplified signal to antenna 174 for transmission. Antenna 174 forms a load for power amplifier 160. It is noted that this load is susceptible to impedance variations due to its operating environment. Power amplifier 160 provides a portion of the output signal to summator 154, via down-mixer and baseband unit 164 and phase shifter unit 162, thereby generating feedback loop output signal 182. Feedback loop output signal 182 constitutes a feedback signal for controlling the gain of power amplifier 160 and maintaining transmitter block 150 in the linear mode of operation.

Baseband filter unit 156 also provides a filtered error signal 190 to summator 166. Summator 166 combines error signal 190 with signal 184 from adaptor 172 and provides the result to AGC 168. AGC 168 constitutes a linear gain control circuit of isolator elimination circuit 176. Adaptor 172 controls the gain of AGC 168 by altering the output signal of AGC 168. Adaptor 172 controls also the gain of adjustable driver 159. AGC 168 provides the output signal to summator 170, where it is combined with input signal 180. Summator 170 provides the resulting error signal 194 to adaptor 172, which produces two output control signals 186 and 188. Control signal 186 adjusts the gain of attenuator 152, and control signal 188 adjusts phase shifter 162. Adaptor 172 produces control signals 184, 186 and 188 based on input signal 180 and error signal 194.

In comparing the linear transmitter 150 of the present invention with that of the prior art, it is significant to note the presence of adjustable driver 159. Its gain, which is dynamically controlled by adaptor 172, depends on information contained in error signals 190 and 194. Since adjustable driver 159 adds additional gain to feedback loop 178, it is possible to use low-power isolator elimination circuitry, yet maintaining required loop gain and linearity of the system 150.

Claims

1. Device for minimizing performance degradation of a linear transmitter block (150) of a radio communication device in the presence of antenna interference, the linear transmitter block including a main amplifier feedback loop (178) and an auxiliary loop (176), the device comprising an adjustable driver (159), connected within said main amplifier feedback loop (178) and further connected to said auxiliary loop (176),

said adjustable driver (159) receiving an input signal to be amplified from said main amplifier feedback loop (178),

said adjustable driver (159) receiving a gain control signal from said auxiliary loop (176),

said adjustable driver (159) amplifying said received input signal, according to said gain control signal, and

said adjustable driver (159) providing said amplified signal to said main amplifier feedback loop (178).

2. The device according to claim 1, wherein said main amplifier loop (178) includes an attenuator (152), a baseband filter (156), an up-mixer and RF filter unit (158), a RF power amplifier (160), a down-mixer and baseband filter unit (164), a phase shifter (162) and a summator (154),

wherein said summator (154) is connected to said attenuator (152), to said base band filter (156) and to said phase shifter unit (162),

wherein said adjustable driver (159) is connected to said up-mixer and RF filter unit (158) and to said RF power amplifier (160),

said down-mixer and baseband filter unit (164) is connected to said RF power amplifier (160) and to said phase shifter unit (162);

wherein said auxiliary loop (176) includes an adaptor (172), an AGC (168) and two summators (166) and (170),

said summator (166) is connected to said baseband filter unit (156), to said adaptor (172) and to said AGC (168),

said summator (170) is connected to said attenuator (152), to said AGC (168) and to said adaptor (172), and

said adaptor (172) is connected to said AGC (168), to said attenuator (152), to said phase shifter unit (162) and to said adjustable driver (159).

3.   The device according to claim 2, wherein

said input signal to be amplified constitutes a first baseband error signal, filtered by said baseband filter (156) and up-converted by said up-mixer and RF filter unit (158),

said first baseband error signal being provided by said summator (154), and constitutes a sum of a baseband signal and an output signal of said main amplifier feedback loop (178),

said baseband signal being an input baseband signal attenuated by attenuator (152), said attenuator controlled by a first output signal from said adaptor (172), and

said output signal of said main amplifier feedback loop (178) being a result of down-converting by said down-mixer and baseband filter unit (164) and phase shifting by said phase shifter (162), of a portion of an output RF signal provided by said RF power amplifier (160), wherein said phase shifter being controlled by a second control signal from said adapter (172).
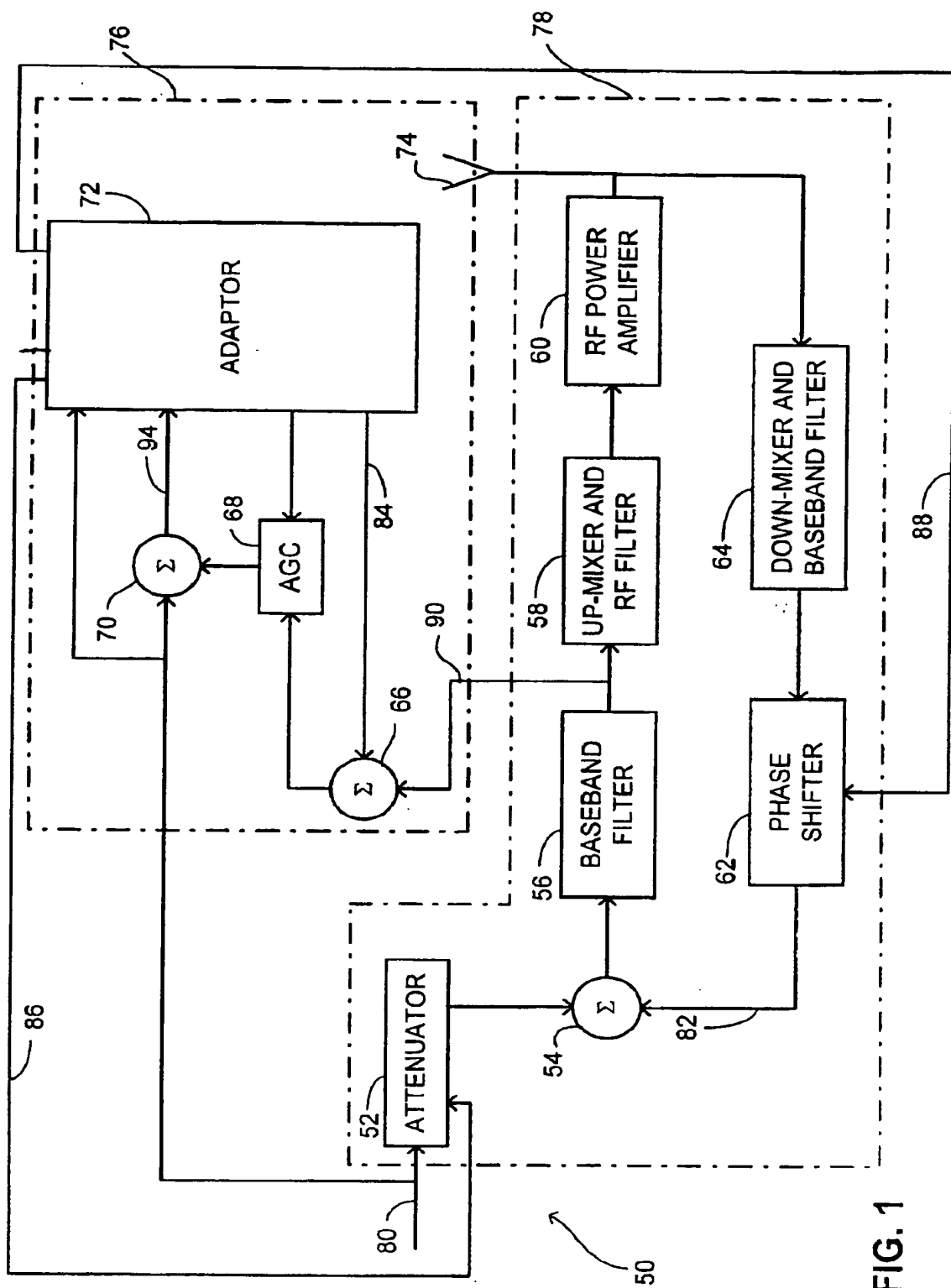
4. The device according to claim 3, wherein said gain control signal is provided by said adaptor (172),
said gain control signal is a result of a comparison between said input baseband signal and a second baseband error signal, provided by said summator (170),
said second baseband error signal is a sum of said input baseband signal and an output signal from said AGC (168),
said output signal is a result of a comparison between said gain control signal and a third baseband error signal provided by said summator (166), and
said third baseband error signal is a sum of a third output signal from said adapter (172) and said first baseband error signal, provided by said baseband filter (156).
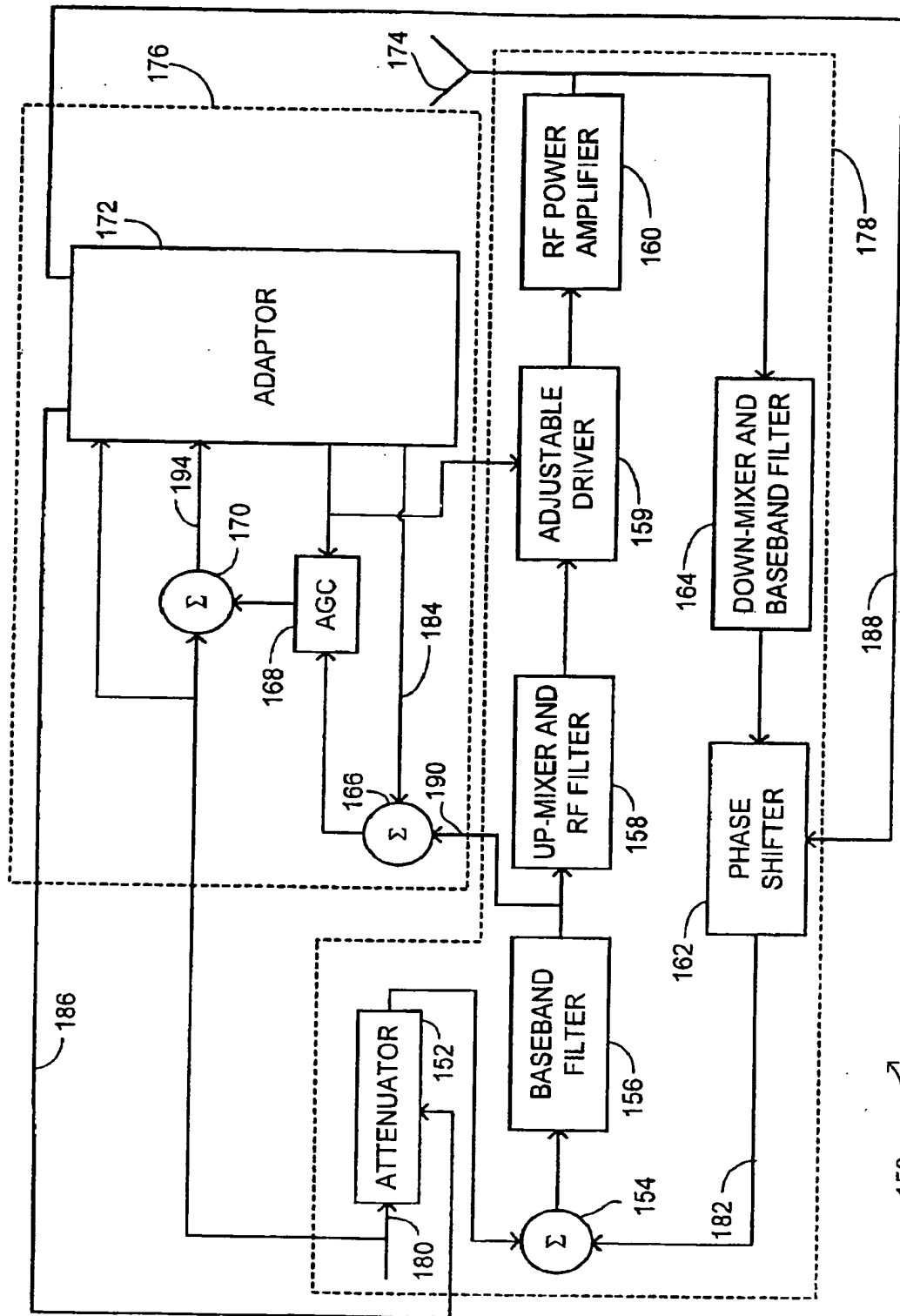
FIG. 1

FIG. 2

(51) International Patent Classification⁷: H04B 1/04,
H04L 27/36, H03F 1/32, H03G 3/20, 3/30, H03C 3/08

(21) International Application Number: PCT/IB01/00254

(22) International Filing Date: 26 February 2001 (26.02.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0004557.5   25 February 2000 (25.02.2000)   GB

(71) Applicant (for all designated States except US): MO-
TOROLA ISRAEL LIMITED [IL/IL]; Kremenetski
Street 16, 67899 Tel Aviv (IL).

(72) Inventors; and
(75) Inventors/Applicants (for US only):   BEN-AYUN,
Moshe [IL/IL]; 27 Hayasmin_Street, P.O.Box 3026,

73142_Shoham (IL), ROZENTAL, Mark [IL/IL]: Apart-
ment 8, Herzel Street 29, 76560 Rehovot (IL).

(81) Designated States (national): AL, AM, AU, AZ, BA, BB,
BG, BR, BY, CA, CH, CN, CU, CZ, EE, GE, GH, GM, HR,
HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS,
LT, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, RO,
RU, SD, SG, SI, SK, SL, TJ, TM, TT, UA, UG, US, UZ,
VN, YU, ZW.

(84) Designated States (regional): European patent (AT, BE,
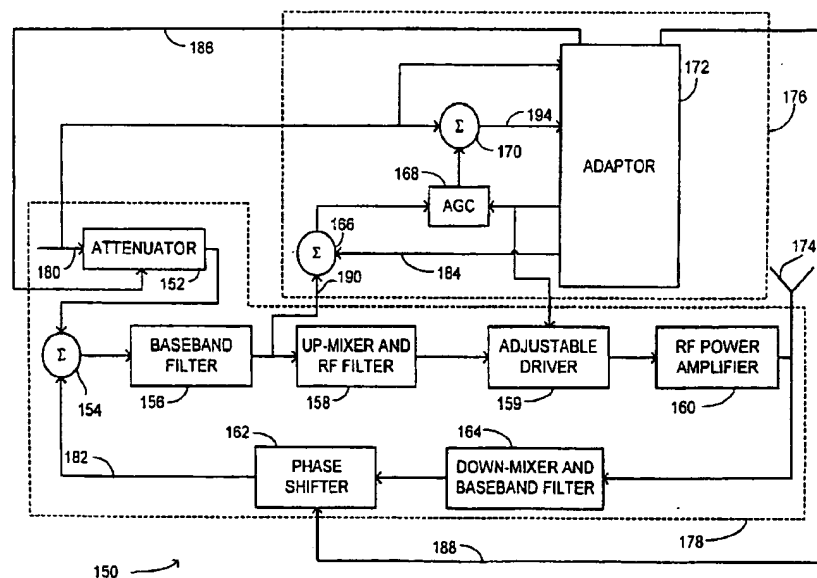CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC,
NL, PT, SE, TR).

Published:
— with international search report

(88) Date of publication of the international search report:
21 February 2002

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS FOR LINEAR TRANSMITTER WITH IMPROVED LOOP GAIN STABILIZATION

(57) Abstract: A device for a linear transmitter (150) with improved loop gain stabilization. The linear transmitter (150) includes
a main amplifier loop (178) and an auxiliary loop (176). The device includes an adjustable driver (159), connected within the main
amplifier feedback loop (178) and further connected to the auxiliary loop (176). The adjustable driver (159) receives an input signal
from main amplifier feedback loop (178), amplifies it in accordance with a gain control signal received from the auxiliary loop (176)
and provides the amplified signal to main amplifier feedback loop (178).

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H04B1/04   H04L27/36   H03F1/32   H03G3/20   H03G3/30
     H03C3/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   H04B   H04L   H03F   H03G   H03C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 675 286 A (GAILUS PAUL H ET AL) 7 October 1997 (1997-10-07) cited in the application abstract column 2, line 41 -column 4, line 39 figure 2	1-4
Y	US 5 423 082 A (GAILUS PAUL H ET AL) 6 June 1995 (1995-06-06) abstract column 2, line 34 -column 5, line 16 figure 1	1-4
A	US 5 752 171 A (AKIYA MAKOTO) 12 May 1998 (1998-05-12) the whole document	1-4

☐ Further documents are listed in the continuation of box C.   ☒ Patent family members are listed in annex.

° Special categories of cited documents :

'A' document defining the general state of the art which is not considered to be of particular relevance

'E' earlier document but published on or after the international filing date

'L' document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

'O' document referring to an oral disclosure, use, exhibition or other means

'P' document published prior to the international filing date but later than the priority date claimed

'T' later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

'X' document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

'Y' document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

'&' document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 August 2001	22/08/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340-2040, Tx. 31 651 epo nl, Fax: (+31–70) 340-3016	Lindhardt, U

Form PCT/ISA/210 (second sheet) (July 1992)

1

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5675286	A	07-10-1997	NONE		
US 5423082	A	06-06-1995	CA	2161901 A	05-01-1995
			CN	1125497 A,B	26-06-1996
			EP	0710411 A	08-05-1996
			WO	9501009 A	05-01-1995
			US	5542096 A	30-07-1996
US 5752171	A	12-05-1998	JP	8316756 A	29-11-1996
			AU	698379 B	29-10-1998
			AU	5245196 A	05-12-1996
			GB	2301242 A,B	27-11-1996